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# Electronic Circuits Testing and Applications

Vehicle Electronics ACHA4031

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## 1 Task 3

### 1.1 Scope Time Division Calculations (6)

#### **For Known Capacitance and Resistance:**

Capacitance (C) = 1 $\mu$ F

Resistance (R) = 100 $\Omega$

Time Constant ( $\tau$ ) =  $R \times C$

$$= 100 \times 1 \times 10^{-6}$$

$$= 0.0001$$

Complete waveform = 40  $\tau$

$$= 40 \times 0.0001$$

$$= 4\text{ms}$$

**Or**

Wave Frequency ( $f$ ) = 250Hz

Wave Period =  $\frac{1}{f}$

$$= \frac{1}{250}$$

$$= 0.004\text{s OR } 4\text{ms}$$

Number of time divisions ( $Td$ ) = 10

$$Td = \frac{\text{Wave Period}}{\text{Wave Frequency (f)}}$$

$$= \frac{0.004}{250}$$

$$= 0.000016\text{s OR } 16\mu\text{s}$$

## 1.2 Function Generator output square wave (6)

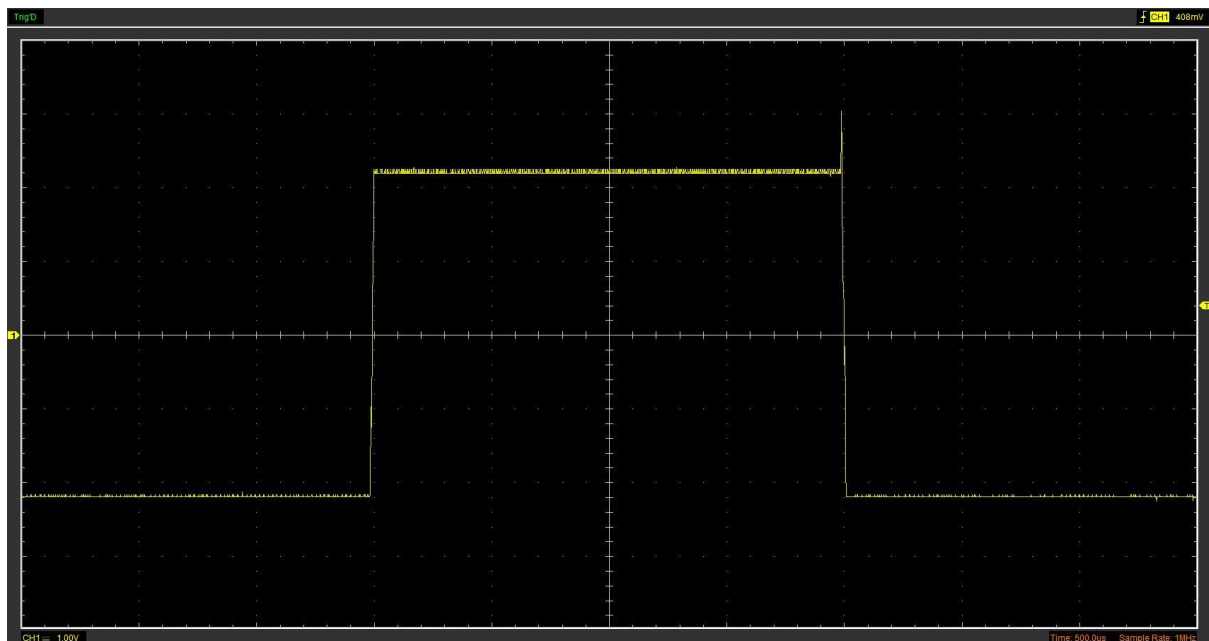


Figure 1- Function Generator Screenshot

$$\begin{aligned} FGenfrequency &= \frac{1}{40\tau} \\ &= \frac{1}{40(0.0001)} \\ &= 250Hz \end{aligned}$$

### 1.3 Capacitor charge and discharge wave marked at correct points. (6)

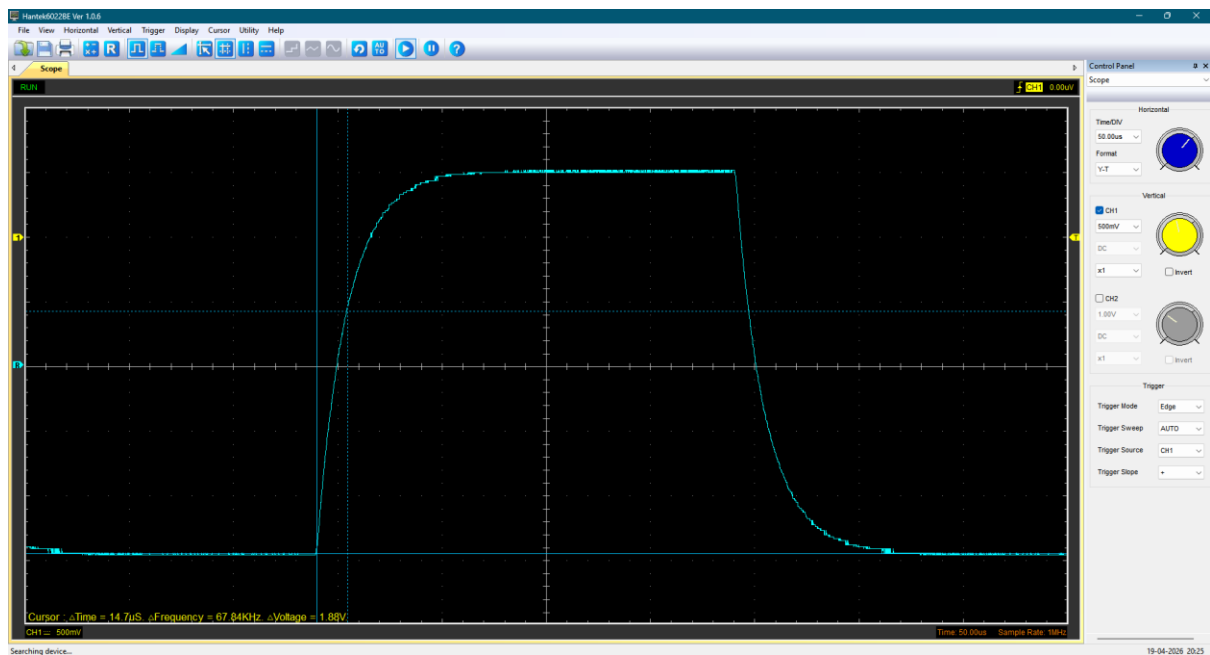


Figure 2 - Capacitor wave Screenshot 1 (charge)

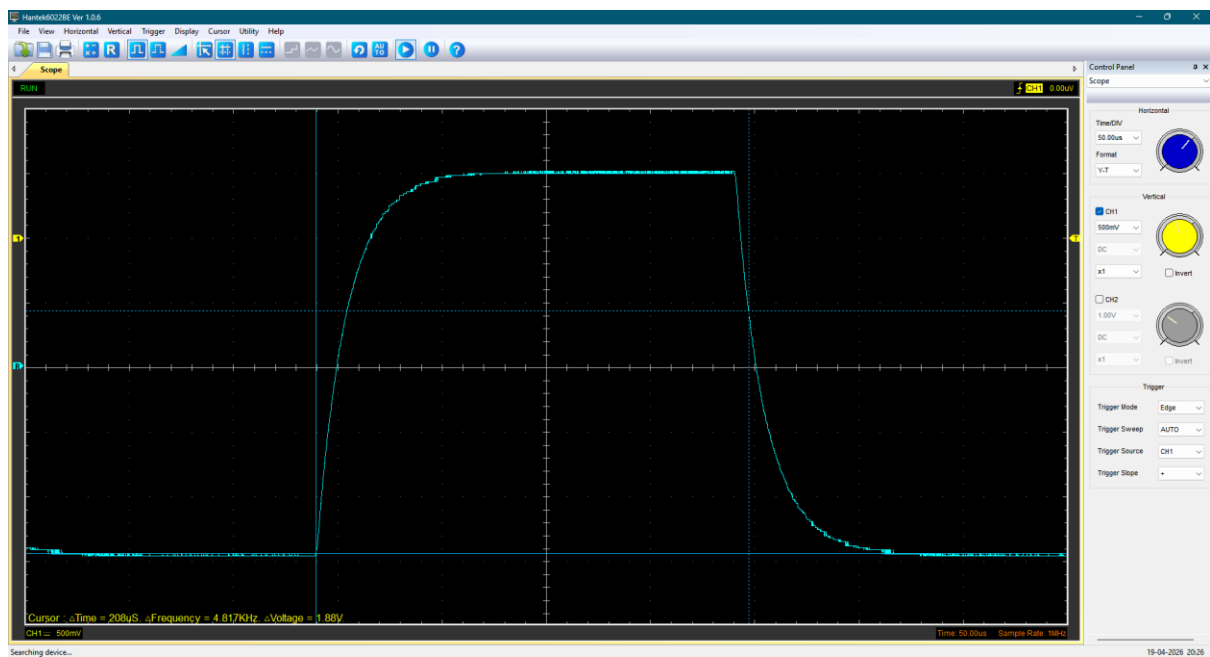


Figure 3- Capacitor wave Screenshot 2 (discharge)

## 1.4 Basic Capacitor Calculations (6)

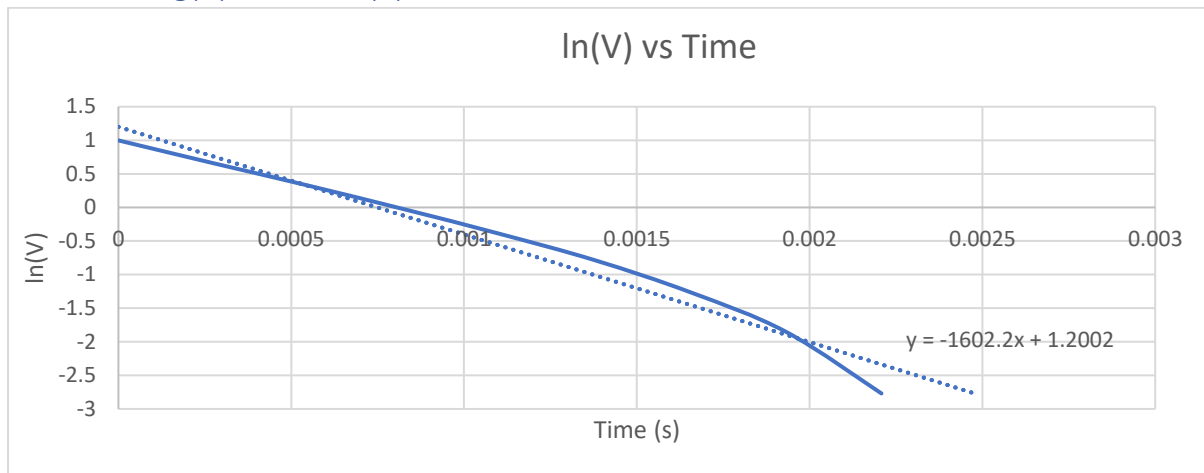
Time Constant ( $\tau$ ) =  $R \times C$

$$\begin{aligned}\text{Capacitance (c)} &= \frac{\tau}{R} \\ &= \frac{0.0001}{100} \\ &= 0.000001\text{F OR } 1\mu\text{F}\end{aligned}$$

## 1.5 Capacitor discharge table (5)

Table 1- Capacitor Discharge Table

| Time (s) | Voltage (V) | ln (V)      | $dy = y_2 - y_1$<br>$dy = \ln(V)_2 - \ln(V)_1$ | $dx = x_2 - x_1$<br>$dx = \text{Time}_2 - \text{Time}_1$ | $dy/dx$      |
|----------|-------------|-------------|------------------------------------------------|----------------------------------------------------------|--------------|
| 0        | 2.7137      | 0.99831302  | x                                              | x                                                        | x            |
| 0.000276 | 1.9294      | 0.65720907  | -0.34110394                                    | 0.000276                                                 | -1235.883854 |
| 0.000552 | 1.3804      | 0.32237331  | -0.33483576                                    | 0.000276                                                 | -1213.173049 |
| 0.000828 | 0.9725      | -0.0278852  | -0.35025852                                    | 0.000276                                                 | -1269.052593 |
| 0.001104 | 0.6745      | -0.3937836  | -0.3658984                                     | 0.000276                                                 | -1325.71884  |
| 0.00138  | 0.4549      | -0.78767766 | -0.39389406                                    | 0.000276                                                 | -1427.152395 |
| 0.001656 | 0.2824      | -1.26443077 | -0.47675311                                    | 0.000276                                                 | -1727.366337 |
| 0.001932 | 0.1569      | -1.85214662 | -0.58771585                                    | 0.000276                                                 | -2129.405239 |
| 0.002208 | 0.0627      | -2.76939383 | -0.91724721                                    | 0.000276                                                 | -3323.359464 |
| 0.002484 | 0           |             |                                                |                                                          |              |

1.6 Plot  $\log(V)$  Gradient (5)*Figure 4- Log Discharge Curve*

## 1.7 Gradient Calculations and Compare (8)

### **Gradient Calculation [GC]** (from figure 4)

$$\begin{aligned}\frac{dy}{dx} &= \frac{y_2 - y_1}{x_2 - x_1} \\ &= \frac{-2.2 - 1.0}{0.002 - 0} \\ &= \frac{-3.2}{0.002} \\ &= -1600\end{aligned}$$

### **Marker Calculation [MC]** (from table 1)

$$\begin{aligned}\text{Mean } dy/dx &= \frac{-13651.111771}{8} \\ &= -1706.39\end{aligned}$$

$$\Delta[\text{GC}][\text{MC}] = -1706.39 - (-1692.2)$$

$$\% \text{ error} = 1692.214.19 \times 100 \approx 0.84\%$$

*Table 2- Capacitance Comparison Table*

|                      | Capacitance | Delta        | Percentage difference |
|----------------------|-------------|--------------|-----------------------|
| Actual               | 1 $\mu$ F   | x            | X                     |
| Marker Calculation   | 5.9 $\mu$ F | +4.9 $\mu$ F | 142.03%               |
| Gradient Calculation | 6.2 $\mu$ F | +5.2 $\mu$ F | 144.40%               |

## 1.8 Capacitor Uses (5)

- Invertors for Hybrid and Electrical Vehicles (Montanari et al., 2009)
- Vehicular power electronic circuits (Marati, Gupta and Vaithilingam, 2020)
- High temperature DC link applications in automotive traction drives (Winterborne et al., 2013)
- Braking Systems (Jacqueline, Bunel and Lengignon, 2020)
- 12 V stop–start (TSS), 42 V stop–start (FSS), and 42 V transient power assist (TPA) (Ashtiani, Wright and Hunt, 2006)
- Voltage balancing for series connected battery packs (Liu et al., 2020)
- Discharge Ignition for Dual-cylinder Motorcycles (Su, Tsai and Chen, 2020)
- Voltage Control for Electric Motorcycle Chargers (Jettanasen and Pothisarn, 2020)
- Energy capture in rubber-tired gantry cranes (Burke and Miller, 2026)
- Local Energy Generation (Diesel Generator etc.) (Kötz and Carlen, 2000)

## 1.9 Inaccuracies Question (4)

As can be seen above, the difference between the nominated and calculated values are considerable. This will be due to a small range of factors including inaccuracies in the provided equipment and also in human measuring error. Cheap equipment such as the oscilloscope and function generator used can introduce unwanted resistance into the calculations, therefore obscuring the measured final outputs. (Reed, 2024) As stated in the HANTEK (2021) guidance manual, the oscilloscope should warm up for 20 minutes before use. This practice was not observed during the experiment, therefore potentially affecting the accuracy of the already unreliable equipment.

Human error may have also played a part in several areas of the experimental process such in as the setup of the equipment, recording of the data, placement of cursors within the Hantek software, use of the function generator (including choosing appropriate values) and accurately post processing data. One small mistake in any part of the process may have a snowball effect and directly interfere with other results or readings, creating a large discrepancy in results.

Despite the inaccuracies, the expected general trends can still be observed providing students with a good understanding of how the experiment should be performed and the expected outcome.

### 1.10 Risk Question (10)

New vehicles rely greatly on Controller CANbus (Computer Area Network) systems to allow communications between ECUs (Boland et al., 2021). While this is a predominantly efficient and secure process, it was not designed with cybersecurity in mind. This makes it vulnerable to several attack methods such as message spoofing, replay attacks, and denial-of-service. The standard ISO/SAE 21434:2021 (ISO and SAE, 2021) provides a detailed framework to safeguard against risks across the vehicular network.

A notable mitigation method is known as secure system design. This involves splitting the vehicle's network so that ECUs of increased sensitivity (e.g. braking and steering systems) are separate from less secure points of entry like infotainment and external interfaces (internet). Gateway ECUs can enforce filtering rules. This ensures only authorised messages pass between network segments. This reduces the attack surface significantly (Hakim, 2024).

Another important measure is authentication and encryption. Traditional CAN lacks security, implementing higher-layer protocols such as CAN-FD with authentication (e.g. Message Authentication Codes) ensures that ECUs can verify the legitimacy of messages. Although encryption can introduce latency, lightweight methods can balance performance with security—an important consideration in real-time automotive systems (Xiao et al., 2020).

Intrusion Detection Systems (IDS) are paramount. These systems oversee CAN traffic, looking for anomalies such as high message frequency or unauthorised IDs. By creating a pattern of standard behaviours, IDS can identify potential risks in real time and deploy defensive responses, such as isolating compromised ECUs. This agrees with ISO/SAE 21434's emphasis on persistent monitoring and incident response (Lampe and Meng, 2022).

The standard also specifies the importance of software updates and development. Over-the-air (OTA) updates are to be cryptographically signed and certified prior to installation in order to prevent the injection of malicious firmware. In addition, secure boot mechanisms ensure ECUs may only run recognised software, protecting against outside threats (Kornaros et al., 2020).

## 2 References

- Ashtiani, C., Wright, R. and Hunt, G. (2006). Ultracapacitors for automotive applications. *Journal of Power Sources*, 154(2), pp.561–566. doi:<https://doi.org/10.1016/j.jpowsour.2005.10.082>.
- Boland, H.M., Burgett, M.I., Etienne, A.J. and Iii, R.M.S. (2021). *An Overview of CAN-BUS Development, Utilization, and Future Potential in Serial Network Messaging for Off-Road Mobile Equipment*. [online] [www.intechopen.com](http://www.intechopen.com). IntechOpen. Available at: <https://www.intechopen.com/chapters/77277> [Accessed 19 Apr. 2026].
- Burke, A. and Miller, J., R (2026). *Radware Bot Manager Captcha*. [online] [iop.org](http://iop.org). Available at: <https://iopscience.iop.org/article/10.1149/2.F08081IF/pdf> [Accessed 19 Apr. 2026].
- Hakim, K. (2024). *CANvas: Open-Source CAN-Bus Simulation and Modular Cybersecurity Experimentation*. [online] [uclovain.be](http://uclovain.be). Available at: <https://thesis.dial.uclouvain.be/server/api/core/bitstreams/26a57442-52e6-4f00-a9f7-92cee39b5eed/content> [Accessed 19 Apr. 2026].
- Hantek (2021). *USER'S MANUAL Hantek6022BE*. [online] Available at: [https://www.hantek.com/uploadpic/hantek/files/20210609/Hantek6022BE\\_Manual\\_EN.pdf](https://www.hantek.com/uploadpic/hantek/files/20210609/Hantek6022BE_Manual_EN.pdf) [Accessed 19 Apr. 2026].
- ISO and SAE (2021). *ISO/SAE 21434:2021*. [online] Available at: <https://www.iso.org/standard/70918.html> [Accessed 19 Apr. 2026].
- Jacqueline, S., Bunel, C. and Lengignon, L. (2020). Outstanding reliability performances of Silicon capacitors for 200°C automotive applications. *2020 IEEE 70th Electronic Components and Technology Conference (ECTC)*, [online] pp.2133–2138. doi:<https://doi.org/10.1109/ectc32862.2020.00331>.
- Jettanasen, C. and Pothisarn, C. (2020). The Electrical Motorcycle Charger for Application in a Residence. *E3S Web of Conferences*, [online] 186, p.03002. doi:<https://doi.org/10.1051/e3sconf/202018603002>.
- Kornaros, G., Tomoutzoglou, O., Mbakoyiannis, D., Karadimitriou, N., Coppola, M., Montanari, E., Deligiannis, I. and Gherardi, G. (2020). Towards holistic secure networking in connected vehicles through securing CAN-bus communication and firmware-over-the-air updating. *Journal of Systems Architecture*, 109, p.101761. doi:<https://doi.org/10.1016/j.sysarc.2020.101761>.

- Kötz, R. and Carlen, M. (2000). Principles and applications of electrochemical capacitors. *Electrochimica Acta*, [online] 45(15-16), pp.2483–2498. doi:[https://doi.org/10.1016/s0013-4686\(00\)00354-6](https://doi.org/10.1016/s0013-4686(00)00354-6).
- Lampe, B. and Meng, W. (2022). *IDS for CAN: A Practical Intrusion Detection System for CAN Bus Security | IEEE Conference Publication | IEEE Xplore*. [online] [ieeexplore.ieee.org](https://ieeexplore.ieee.org). Available at: <https://ieeexplore.ieee.org/abstract/document/10001536> [Accessed 19 Apr. 2026].
- Liu, K., Yang, Z., Tang, X. and Cao, W. (2020). Automotive Battery Equalizers Based on Joint Switched-Capacitor and Buck-Boost Converters. *IEEE Transactions on Vehicular Technology*, [online] 69(11), pp.12716–12724. doi:<https://doi.org/10.1109/TVT.2020.3019347>.
- Marati, N., Gupta, R.G. and Vaithilingam, B. (2020). Multilayer Ceramic Capacitors Crisis Management in Automotive Industry. *2020 IEEE International Conference on Power Electronics, Smart Grid and Renewable Energy (PESGRE2020)*. doi:<https://doi.org/10.1109/pesgre45664.2020.9070770>.
- Montanari, D., Saarinen, K., Scagliarini, F., Zeidler, D., Niskala, M. and Nender#, C. (2009). Film Capacitors for Automotive and Industrial Applications. *Assemblies & Materials Association*, [online] 29. Available at: <https://canada.newark.com/pdfs/techarticles/kemet/FilmCapsAuto.pdf> [Accessed 19 Apr. 2026].
- Reed, C. (2024). *Function Generators: Your Ultimate Buying Guide - Keysight Technologies*. [online] [Keysight.com](https://www.keysight.com). Available at: <https://www.keysight.com/used/us/en/knowledge/guides/signal-generator-buying-guide/function-generator-buying-guide> [Accessed 19 Apr. 2026].
- Su, J.-C., Tsai, C.-T. and Chen, J.-X. (2020). Implementation of a Capacitive Discharge Ignition for Dual-cylinder Motorcycles. *Sensors and Materials*, 32(1), p.263. doi:<https://doi.org/10.18494/sam.2020.2576>.
- Winterborne, D., Ma, M., Wu, H., Pickert, V. and Shah, L. (2013). Capacitors for high temperature DC link applications in automotive traction drives: Current technology and limitations. *European Conference on Power Electronics and Applications (EPE)*. [online] doi:<https://doi.org/10.1109/EPE.2013.6634382>.
- Xiao, Y., Shi, S., Zhang, N., Lou, W. and Hou, Y.T. (2020). Session Key Distribution Made Practical for CAN and CAN-FD Message Authentication. *Annual Computer Security Applications Conference*, pp.681–693. doi:<https://doi.org/10.1145/3427228.3427278>.

